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Surface Recombination of Excitons in Solar Cells

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Abstract: ***We studied the influence of parameters that govern the surface recombination of excitons in a silicon solar cell subjected to a monochromatic illumination.***

In this study we considered two values of the exciton binding coefficient, $b = 3\times10^{-7} cm^3 s^{-1}$ and $b = 10^{-15} cm^3 s^{-1}$, corresponding to strong coupling and weak coupling[1-2].We also defined a recombination velocity of excitons S_{ex} reflecting loss of these pseudo particles to metal – semiconductor contacts. The study of excitonic recombination boils down to study the influence of recombination velocity S_{ex} on the carrier density. This study found that the recombination of excitons has no impact on electrons density when the coupling is low because exciton and electron diffuse independently with their own diffusion length. However, in the strong coupling we have a negative effect of this parameter on the densities of electrons and excitons. We note also that in these conditions the increase of the electron recombination velocity results in lower of excitons density. These results confirm the coupling theory between electron and exciton developed by R. Corkish and Y. Zhang.

Keywords: Exciton, coupling coefficient, exciton recombination, excitonic conversion

I. Introduction

Production of photovoltaic current passes through the generating excitons which dissociate thereafter free electrons and holes under the action of an electric field. Indeed, the absorption of adequate energy photon leads to the generation of pairs electron - hole. The electron and hole forming this pair may be "free" or bound by the energy level occupied by the electron [3-10]. In the latter case there is obtained an exciton, which can move within the material, dissociate into free electron and hole, being trapped by a surface defect or capture with an impurity to form an exciton-impurity complex. The objective of our work is to study the influence of surface recombination processes of excitons on the densities of electrons and excitons. These recombinations are modeled by the excitons recombinationvelocity to the rear face S_{ex}[11].Moreover, with a view to verify the theory of electron-exciton coupling developed by Zhang and Corkish we studied the effect of the electron recombination velocity on theexcitons density. We consider a model of solar cell silicon n+ p simplified.

The contribution of the emitter is neglected and the excitation energy is low.

II. Theoretical model

We Consider the basic model of Green and Zhang, only minority carriers in the p- region are considered. The problem is to determine electrons and excitonsdensities between the positions x = 0 (the junction) and x = H (the back side). The distribution of carriers is governed by two coupled differential equations found in articles by Zhang and Corkish [1-2].

$$D_e d^2 \frac{\Delta n_e}{dx^2} = \frac{\Delta n_e}{\tau_e} + b(\Delta n_e N_A - \Delta n_{ex} n^*) - G_{e0}\exp[-\alpha x] \quad (1)$$

$$D_{ex} d^2 \frac{\Delta n_{ex}}{dx^2} = \frac{\Delta n_{ex}}{\tau_{ex}} - b(\Delta n_e N_A - \Delta n_{ex} n^*) - G_{ex0}\exp[-\alpha x] \quad (2)$$

Solving this equation system involves the following boundary conditions [11]:

<u>At the junction</u>:

$\Delta n_e (0) = 0$ (3)

$\Delta n_{ex} (0) = 0$ (4)

<u>At the rear face</u>

Ошибка!(5)

Ошибка!(6)

S_e and $S_{ex}$are respectively the recombination velocity of electrons and excitons in the rear surface.

b_s is the surface conversion velocity of excitonsinto free pairs electron-hole [11].

Indeed $S_e \to \infty$corresponds to an ohmic contact and Se = 0 to a perfect surface .

Equations (3) and (4) respectively reflect the non- accumulation of electrons and perfect dissociation of excitons into free electrons and holes at the junction while the equations (5) and (6) are the phenomena of electrons and excitonsrecombination and excitonicconversions to the back surface.

III. Results and discussion

3.1. Effect of the excitonrecombination velocity on theexciton density

The exciton recombination velocity S_{ex}translated, among others, the loss of excitons trapped at the semiconductor– metal contact. We study the influence of this parameter on the densities of electrons and excitons considering both limit values of the binding coefficient of exciton $b = 10^{-15} cm^3.s^{-1}$ and $b = 3\times10^{-7} cm^3.s^{-1}$ which correspond to the weak coupling and strong coupling. The excitation wavelength is λ = 1080 nm.

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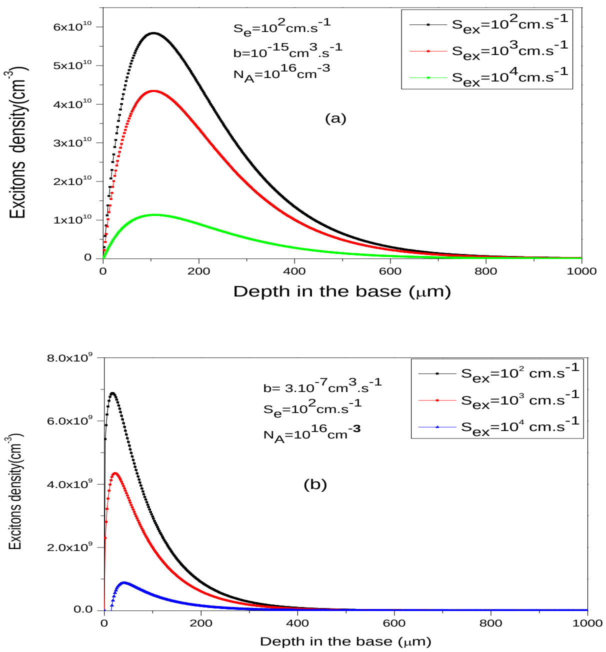

Fig.1. Density of excitons in function of depth in the base to a weak coupling (a) and strong coupling (b), for various values of the exciton recombination velocity

Whatever type of coupling density of excitons decreases with increasing the exciton recombination velocityS_{ex} . This result was expected because increasing the recombination velocity of exciton returns to reduce the number of excitons thus causing a drop in density

3.2. Effect of the exciton recombination velocity on the electron density

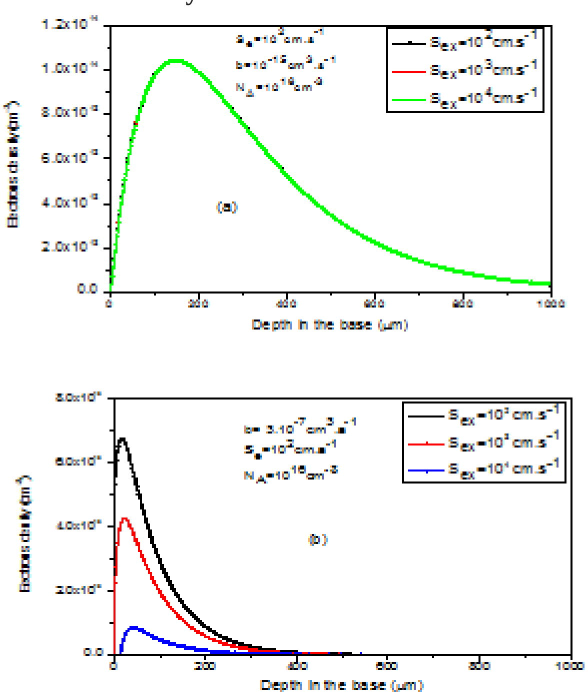

Fig.2. Electrons density infunctionof the depth in the base to a weakcoupling (a) and strongcoupling (b) , for various values of the exciton recombinationvelocity

We find that the recombination velocity S_{ex} has no effect on the electron density when the coupling is weak. Electrons and excitons diffuse in an independent manner in the material, the recombination of excitons will then have no effect on the electron density.

As against a strong coupling, the recombination of excitons leads to a loss of electrons driven by the movement of these excitons.

3.3. Effect of the electron recombination velocity on the electron density

Since electrons and excitons are in certain situations in mutual influence in the material, we want to know if the electron recombination velocity has an impact on the excitons density. For this, we have considered both types of coupling, aexciton recombination velocityS_{ex} = 10^2 cm.$s^{-1}$and a doping level N_A = 10^{16} cm^{-3}. The results obtained led to the Fig. 3 and 4.

We consider two values of the coupling coefficient each corresponding to a coupling type (b = 10-15 cm3.s -1 and b = 3 × 10-7 cm3.s -1).The surface conversion velocity of excitons is set to b_s = 10^3 cm.s^{-1}.

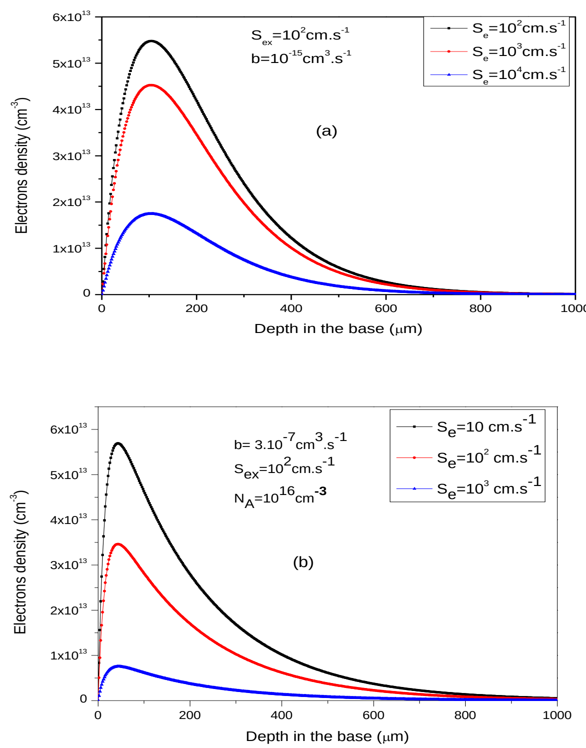

Fig.3. Electron density in function of the depth in the base to a weak coupling (a) and strong coupling (b), for various values of S_e.

Increasing the electronrecombinationvelocity causes a weakening of the electrondensityregardless of the type of

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coupling as the number of electronsdecreases. Thisrecombinationvelocitythus has a negativeeffect on the performance of the solarcell.

3.4. Effect of electronrecombinationvelocity on exciton density

We consider the conditions for obtaining the Fig.3 but considering a surface conversion velocity b_s zero.

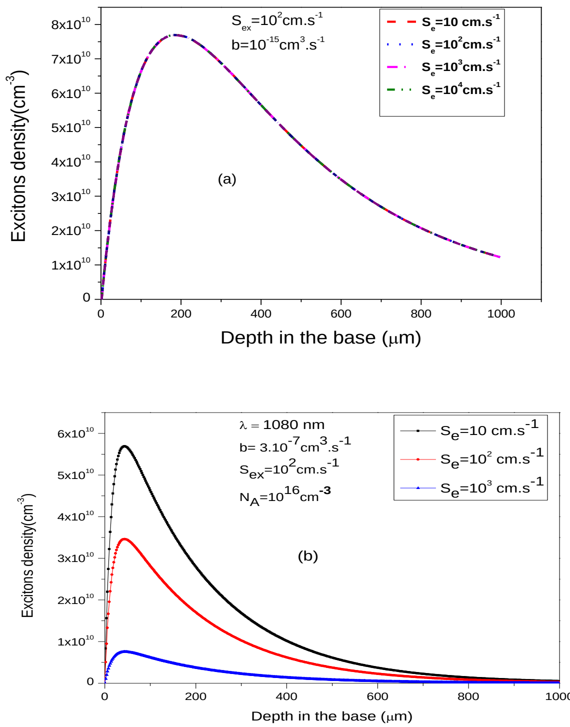

Fig.4. Exciton density in function of depth in the base to a weak coupling (a) and strong coupling (b), for various values of the electrons recombination velocity

The electron recombination velocity has no effect on the exciton density when the coupling is weak. Indeed, a change in the number of electrons does not change the number of excitonspresent since these particles coexist and diffuse independently in the material.

However, when the coupling is strong, the exciton density decreases according to the increase of S_e. The strong coupling being synonymous coupled excitonformation, a recombination of electrons thus reduces excitoncoupled generation. Which will result in a decrease in the exciton density profile generated in the material.

IV. Conclusion

In this article we expanded the work initiated by Kane Swanson, Corkish, Chan and Burgelman on exciton theory in the operation of a solar cell.

Our study, which focused on recombination processes of excitons in a silicon solar cell, confirmed the theory of coupling between electrons and excitons.Indeed, the densities of electrons and excitons decrease with theexciton recombination velocity. The study also revealed that the electron recombination velocity has a negative impact on the density of excitons when the coupling is strong. These results actually show that the strong coupling is synonymous with a strong mutual influence between the electron and exciton, so the recombination of excitons affects the density of electrons.

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